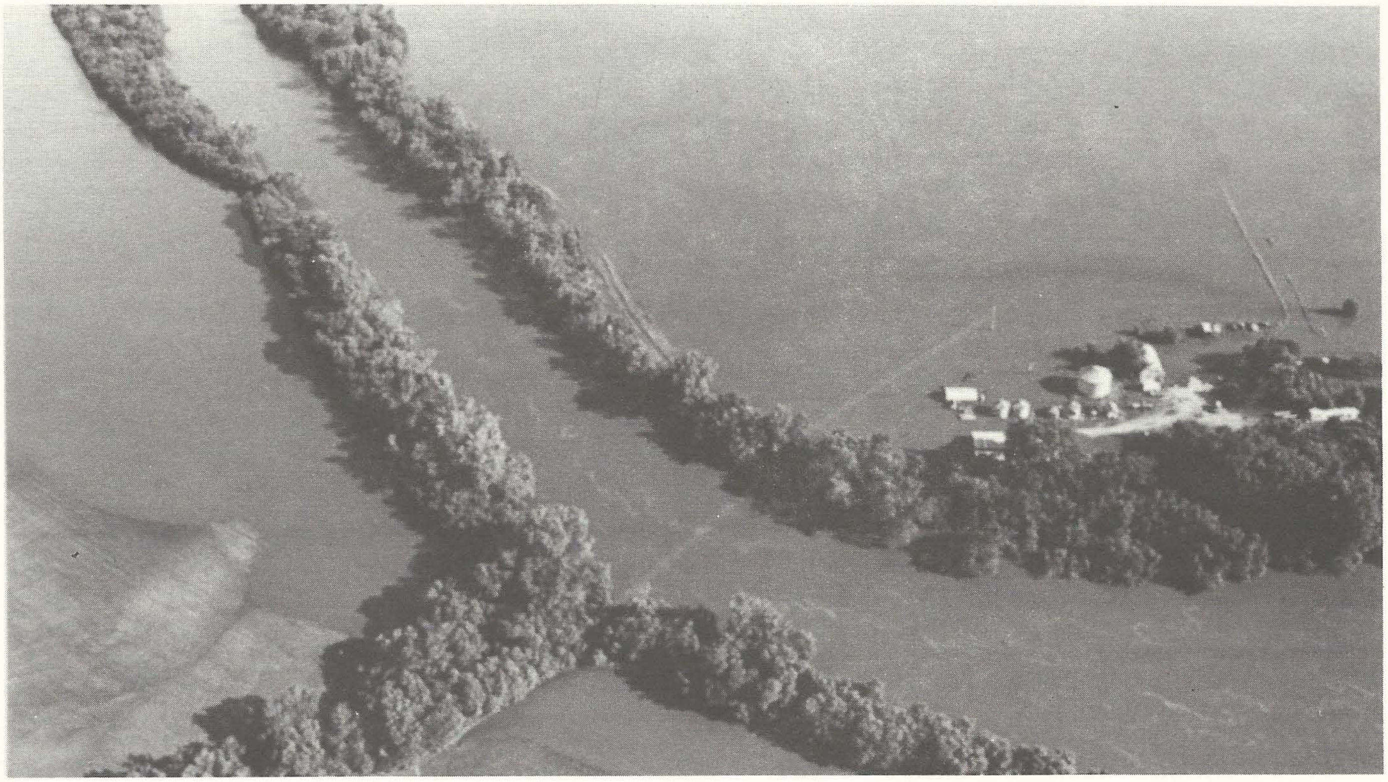
Thompson



FLOODING

and its effect on TREES

United States
Department of
Agriculture

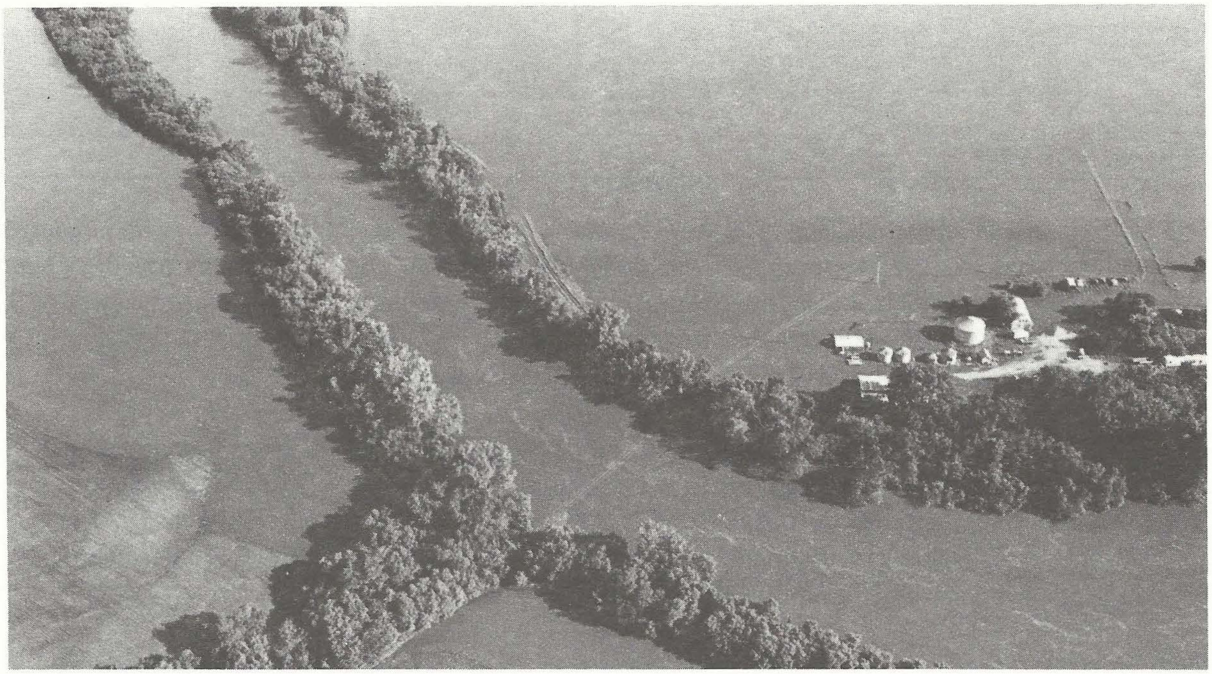
Forest Service

State and Private
Forestry

Northeastern Area

St. Paul, MN

FLOODS



FLOODING

and its effect on TREES

Information Packet

This publication was developed by specialists in Forest Resources Management and Forest Health Protection, USDA Forest Service, Northeastern Area State and Private Forestry, St. Paul, MN.

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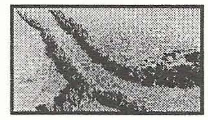
*Cover photograph courtesy of **Mankato Free Press**.*
The river's usual channel is marked by the rows of trees.

September 1993



September 1994

Flooding and its effect on Trees was developed in response to the "Flood of '93" which occurred along the Missouri and Mississippi Rivers and their tributaries. The 1993 edition was distributed in a 3-ring binder which included numerous companion publications. Five-hundred copies of this resource packet were distributed throughout the Midwest and the Great Plains. In addition, selected states reproduced the packet locally and disseminated copies.

Due to the high demand, a second edition of Flooding and its effect on Trees was developed. This second edition (1994) contains all of the original text from the 1993 edition. In addition, three flood-related articles, incorporating field observations and site visits (August 1993 to June 1994 time period), have been included in the 1994 edition. These additional articles can be found following the Bibliography section.

In an attempt to reduce publication costs, the 3-ring binder format and the associated companion publications were eliminated from the 1994 edition. Copies of the companion publications, some of which are referenced in the text, can be requested from the address below. Also, additional copies of this edition are available upon request.

USDA, Forest Service
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1992 Folwell Avenue
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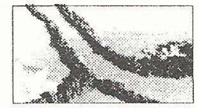
FLOODING
and its effect on TREES



FLOODS

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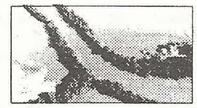

FLOODS

Introduction

The 1993 floods along the Missouri and Mississippi Rivers and their tributaries have caused tremendous losses in terms of human life, homes, businesses and crop production. Bottomland areas have been under water for many weeks. Landowners, homeowners, foresters, park managers, and others are concerned about the long-term effect of the flooding on the forests of the Midwest and the Great Plains.

Purpose and Use of Resource Packet

The purpose of this resource packet is twofold. First, the packet is intended to assist *on-the-ground* natural resource professionals answer flood-related tree questions in both rural and urban areas. Second, the packet can serve the resource professional as a depository for future flood-related publications and information.

FLOODING and its effect on TREES is divided into five sections.

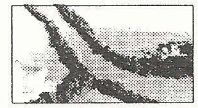
Section 1 - (*yellow divider*)
Addresses the interaction of soil, tree, and flood characteristics and provides flood tolerance ratings for over 90 tree and shrub species.

Section 2 - (*blue divider*)
Focuses on the major insect and disease problems that might be expected on trees following flooding. Symptoms of stress and pest damage are provided including recommended management practices.

Section 3 - (*pink divider*)
Deals with management implications of flooded trees and forest stands. Information is provided on tree recovery, factors affecting management, and salvage considerations.

Section 4 - (*green divider*)
Provides names and addresses for state-level technical assistance pertaining to tree and forest-related flood management and recovery.

Section 5 - (*orange divider*)
A bibliography of all references used in the production of this resource packet.



FLOODS

Flood Tolerance of Trees

Numerous studies have been conducted to help foresters and natural resource managers understand the impact of flooding on trees (see bibliography). The state-of-the-art, however, has not developed sufficiently to warrant a precise statement on the adaptability of a species to a specific flooding situation. Conclusions from different studies are often contradictory, caused in part by the physiological responses of the tree as it interacts with environmental conditions. Since these environmental conditions are not well understood, as well as the difficulty in categorizing tree species over their entire range, flood tolerance predictions must be carefully evaluated in general terms. A brief review of soil, tree, and flood characteristics indicates the complexity of these interactions.

Soils

The following soil-related points are important in understanding flooding effects on trees.

Soil Aeration

Flooding results in poor soil aeration because the supply of oxygen to flooded soil is severely limited. Oxygen deficiency is likely the most important environmental factor that triggers growth inhibition and injury in flooded plants.

pH

Flooding of soil increases the pH of acid soils and decreases the pH of alkaline soils.

Organic Matter

The rate of decomposition of organic matter in flooded soil tends to be only half that in an unflooded soil. The major end products of decomposition of organic matter in flooded soils are carbon dioxide, methane, and humic materials. In addition, high concentrations of ethanol and hydrogen sulfide are produced in waterlogged soils which can be damaging to root systems.

Sedimentation

Deposits of silt or sand as shallow as three inches may seal over and smother tree roots by limiting the supply of oxygen. Species vary in tolerance to sedimentation, but all seedlings are susceptible to root injury. Eastern cottonwood, baldcypress, tupelo, and black willow seedlings can withstand moderate siltation.

Scouring

Strong currents, waves, or suspended particulates may cause soil around the base of the tree to be washed away, exposing tree roots. Exposed roots can lead to not only tree stress but can make the tree more vulnerable to windthrow.

Trees

Various characteristics of a tree affect its flood tolerance with the most prominent presented below.

Height
Tree injury increases in proportion to the percent of crown covered by water. Species that can survive standing in several feet of water for months may die in less than one month when their foliage is completely covered. Few species can tolerate more than one month of complete submersion during the growing season.

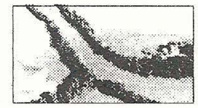
Crown Class
Trees in the dominant crown class survive flooding much better than trees in lower crown classes.

Age
Adult trees tolerate flooding better than overmature trees or seedlings of the same species. Therefore, some species rated as flood tolerant may be quite sensitive in the seedling stage. Seedlings often die because they are pushed over, buried in mud, or uprooted.

Vigor
Tree vigor at time of flooding influences tolerance. Vigorously growing, healthy trees withstand flooding better than less vigorous trees. Tree vigor may be irrelevant, however, if the tree is totally submersed in water.

Roots
Long-term flooding leads to death and decay of large portions of a tree's root system (see section on Management Implications for windthrow problems). During flooding, some species can maintain normal roots in an active or dormant condition; others rely upon new secondary and adventitious roots that may form from the root collar or on the trunk near the water surface. Species unable to either maintain normal roots or grow new ones can quickly die.

Species Variations
Flood tolerance variations within a species are not well understood. Flood tolerance may be an inherited trait and this may explain some of the discrepancies in reports on survival. (Research methodologies also may vary from one study to another, contributing to contradictory conclusions). However, it is generally accepted that some species have greater tolerance for flooding than others (see Tables 1, 2, and 3).



Floods

Determining flood tolerance is complicated by the diverse characteristics of floods.

Season

Flooding during the growing season usually is more harmful to woody plants than flooding during the dormant season. Specifically, trees are most susceptible to flooding in late spring just after the first flush of growth. The timing of a spring flood influences species differentiation. For example, since silver maple flushes earlier than green ash, an early flood might be more damaging to silver maple while a later flood more injurious to green ash.

Duration

The longer trees are exposed to flooding, the greater the potential for injury. Most trees can withstand only 1-4 months with water being continuously over the soil surface. Short periods of flooding during the growing season can be tolerated by most trees. However, if flooding is recurrent and keeps the soil saturated or prevents recovery from previous flooding, injuries will accumulate and serious damage may occur.

Water Level

The depth of water influences flood tolerance. The mortality rate is less for trees in saturated soils than for trees with water covering the soil. After water covers the soil, the depth may have little significance until the lower foliage is covered; research results, however, differ on this point. Tolerance to complete submersion is much lower than tolerance to shallower depths of water.

Temperature and Oxygen

Cold water is less injurious than warm water due to cold water's capacity to hold more dissolved oxygen. Rapidly flowing water (with higher oxygen content) is less harmful than stagnant water.

Mechanical injuries

An often overlooked aspect of flood damage is mechanical injury caused by current, wave action, and floating debris. Young tree plantings may be especially damaged by current and wave action. Floating debris can injure both small and large trees.

Chemicals

Floods may carry various chemicals that have been picked up as runoff from agricultural fields and other areas or from sewage released when treatment facilities become unable to handle large volumes of water. The impact depends upon the type and dosage of chemicals.

Tolerance Categories

Table 1 and **Table 2** present a summary of the research pertinent to flood-tolerant trees and shrubs for three geographical divisions (districts) of the U. S. Army Corps of Engineers: Lower Mississippi Valley, Missouri River, and North Central (see Figure 1). These three divisions include a majority of the forestland flooded during 1993.

Table 1 combines research results from the Lower Mississippi Valley and the Missouri River divisions. Since classification is relative, flood tolerances are best viewed as overlapping from one tolerance category to the next. Where research results differed between Lower Mississippi Valley and Missouri River studies, species are classified into two tolerance categories. The tolerance categories in Table 1 should be interpreted as follows:

Very Tolerant	Able to survive deep, prolonged flooding for more than one year.
Tolerant	Able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year.
Somewhat Tolerant	Able to survive flooding or saturated soils for 30 consecutive days during the growing season.
Intolerant	Unable to survive more than a few days of flooding during the growing season without significant mortality.

Table 2, which presents the results of an Illinois study, is the most comprehensive in the North Central Division. It is important to note that the flood tolerance categories in Table 2 differ from Table 1 in both name and definition. Table 2 tolerance categories should be interpreted as follows:

Tolerant	Most individuals survived more than 150 days of flooding during the growing season.
Somewhat Tolerant	Some individuals killed by less than 90 days of flooding and some individuals survived greater than 150 days of flooding.
Slightly Tolerant	Most individuals survived more than 50 days but less than 100 days of flooding.
Intolerant	Severe effects with less than 50 days of flooding.

Table 3 provides flood tolerance ratings for cultivated woody plants in New York subjected to a growing season flood (June 1972). The species listed in Table 3 are commonly available in the landscape trade and are frequently used in park landscapes and urban settings in the Midwest and the Great Plains. Because Table 3 is based on a short duration flood (10 days), information on the intolerant species (those killed or damaged) will be of the most use to practitioners.

It should be noted that Tables 1-3 classify tree and shrub species tolerance relative to continuous, rather than intermittent, flooding. Some species, for example, might tolerate one year of continuous inundation but only 3-4 months of intermittent flooding. Also, some sites affected by the 1993 floods in the Midwest and the Great Plains had soil saturation up to 90 days prior to flooding. Consequently, the factors of soil saturation prior to flooding and continuous versus intermittent flooding must be considered when predicting the relative flood tolerance of species.

With the exception of the tolerance ratings for hackberry, green ash, and shingle oak, Table 1 is more conservative in its tolerance ratings than Table 2. Table 1 includes more species than Table 2 and is based on a summary of studies from a broader geographical area. Consequently, ***Table 1 is recommended as the "field guide" for foresters and other resource managers who are evaluating flood-damaged trees in the Midwest and the Great Plains.***

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Figure 1

U.S. Army Corps of Engineers Divisional Areas

(Source: Whitlow and Harris 1979)

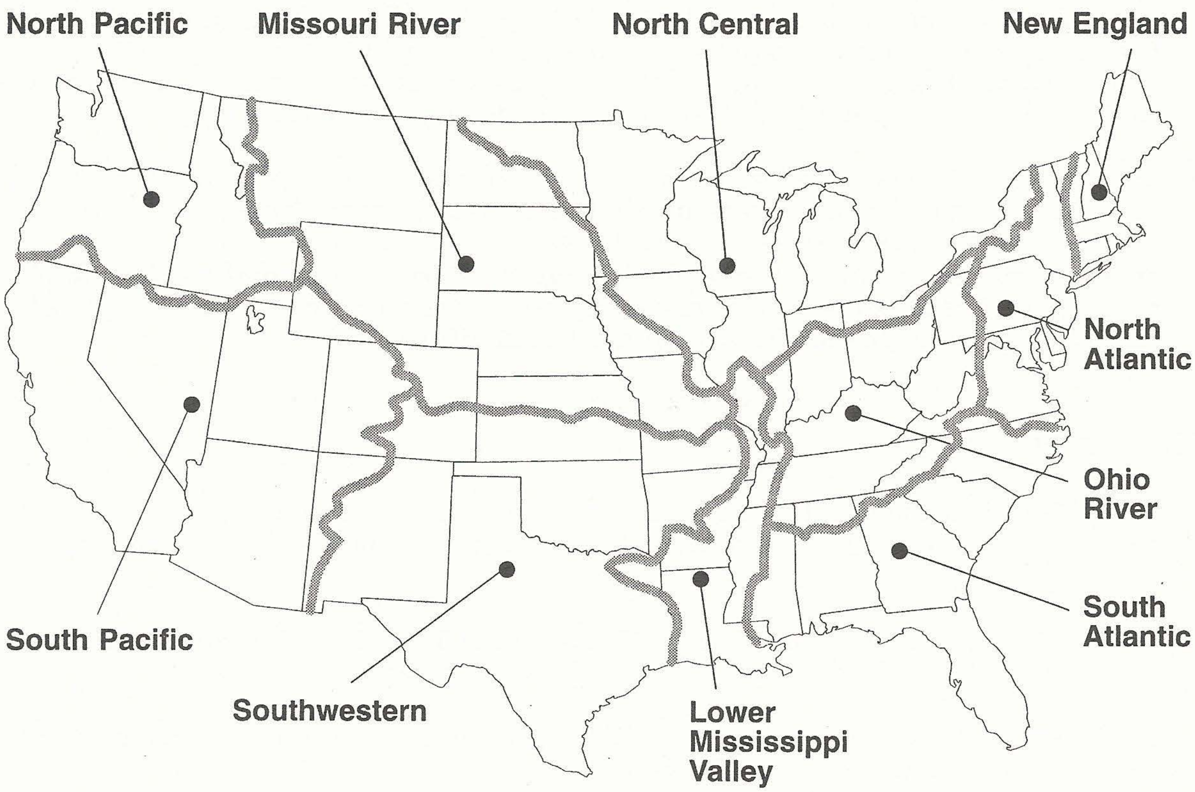

TABLE 1

Relative tolerance of trees and shrubs to flooding during the growing season, Lower Mississippi Valley and Missouri River Divisions. (Source: Whitlow and Harris 1979)

Species	Common Name	Very Tolerant[1]	Tolerant[2]	Somewhat Tolerant[3]	Intolerant[4]
Acer negundo	Boxelder		■	■	
Acer rubrum	Red maple		■		
Acer saccharinum	Silver maple		■	■	
Alnus rugosa	Hazel alder			■	
Betula nigra	River birch			■	
Carya aquatica	Water hickory	■			
Carya cordiformis	Bitternut hickory				■
Carya illinoensis	Pecan	■	■		
Carya laciniosa	Shellbark hickory				■
Carya ovata	Shagbark hickory				■
Carya tomentosa	Mockernut hickory				■
Celtis laevigata	Sugarberry		■		
Celtis occidentalis	Hackberry		■		
Cephalanthus occidentalis	Buttonbush	■			
Cercis canadensis	Redbud				■
Cornus florida	Flowering dogwood				■
Crataegus mollis	Downy hawthorn			■	
Diospyros virginiana	Persimmon		■		
Foresteria acuminata	Swamp privet	■			
Fraxinus americana	White ash		■		
Fraxinus pennsylvanica	Green ash	■	■		
Gleditsia aquatica	Waterlocust	■			
Gleditsia triacanthos	Honeylocust			■	
Gymnocladus dioicus	Kentucky coffeetree				■
Ilex decidua	Deciduous holly	■			
Ilex opaca	American holly			■	
Juglans nigra	Black walnut				■
Liquidambar styraciflua	Sweetgum		■		
Morus rubra	Red mulberry				■
Nyssa aquatica	Water tupelo	■			
Nyssa sylvatica	Blackgum			■	
Pinus echinata	Shortleaf pine				■
Pinus taeda	Loblolly pine				■
Planera aquatica	Waterelm	■			

Table 1 (Relative tolerance of trees and shrubs to flooding) - *continued*

Species	Common Name	Very Tolerant[1]	Tolerant[2]	Somewhat Tolerant[3]	Intolerant[4]
Platanus occidentalis	Sycamore		■	■	
Populus deltoides	Eastern cottonwood		■		
Prunus americana	Wild plum				■
Prunus serotina	Black cherry				■
Quercus alba	White oak				■
Quercus bicolor	Swamp white oak			■	
Quercus falcata	Southern red oak			■	
Quercus imbricaria	Shingle oak		■		
Quercus lyrata	Overcup oak	■			
Quercus macrocarpa	Bur oak			■	
Quercus marilandica	Blackjack oak				■
Quercus nigra	Water oak			■	
Quercus nuttallii	Nuttall oak	■			
Quercus palustris	Pin oak		■		
Quercus phellos	Willow oak			■	
Quercus rubra	Red oak				■
Quercus shumardii	Shumard oak				■
Quercus stellata	Post oak				■
Quercus velutina	Black oak				■
Salix nigra	Black willow	■			
Sassafras albidum	Sassafras				■
Taxodium distichum	Baldcypress	■			
Ulmus alata	Winged elm			■	
Ulmus americana	American elm			■	
Ulmus rubra	Red elm			■	

[1] Very Tolerant: able to survive deep, prolonged flooding for more than 1 year.

[2] Tolerant: able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year.

[3] Somewhat Tolerant: able to survive flooding or saturated soils for 30 consecutive days during the growing season.

[4] Intolerant: unable to survive more than a few days of flooding during the growing season without significant mortality.

TABLE 2

Relative tolerance of Illinois trees to flooding during the growing season. (Source: Bell and Johnson 1974). **NOTE**: *Flood tolerance categories in Table 2 differ from Table 1 in both name and definition.*

Species	Common Name	Tolerant[1]	Somewhat Tolerant[2]	Slightly Tolerant[3]	Intolerant[4]
Acer negundo	Boxelder	■			
Acer saccharinum	Silver maple	■			
Carya ovata	Shagbark hickory		■		
Carya tomentosa	Mockernut hickory			■	
Celtis occidentalis	Hackberry		■		
Cercis canadensis	Redbud		■		
Crataegus mollis	Downy hawthorn	■			
Diospyros virginiana	Persimmon	■			
Juglans nigra	Black walnut		■		
Fraxinus pennsylvanica	Green ash		■		
Gleditsia triacanthos	Honeylocust	■			
Platanus occidentalis	Sycamore	■			
Populus deltoides	Eastern cottonwood	■			
Prunus serotina	Black cherry				■
Quercus alba	White oak			■	
Quercus bicolor	Swamp white oak	■			
Quercus imbricaria	Shingle oak		■		
Quercus macrocarpa	Bur oak	■			
Quercus palustris	Pin oak	■			
Quercus rubra	Red oak			■	
Quercus velutina	Black oak				■
Salix nigra	Black willow	■			
Sassafras albidum	Sassafras				■
Ulmus americana	American elm		■		

[1] Tolerant: most individuals survived more than 150 days of flooding during the growing season.

[2] Somewhat Tolerant: some individuals killed by less than 90 days of flooding and some individuals survived greater than 150 days of flooding.

[3] Slightly Tolerant: most individuals survived more than 50 days but less than 100 days of flooding.

[4] Intolerant: severe effects with less than 50 days of flooding.

TABLE 3

Relative tolerance of cultivated species to short-term flooding during the growing season. (Source: White 1973)

Species	Common Name	Tolerant[1]	Intolerant[2]
Shade Trees			
Acer platanoides	Norway maple		■
Acer rubrum	Red maple	■	
Acer saccharum	Sugar maple		■
Betula papyrifera	Paper birch		■
Betula populifolia	Gray birch		■
Cercis canadensis	Redbud		■
Cladrastis lutea	Yellowwood		■
Cornus florida	Flowering dogwood		■
Cornus florida "Cloud 9"			■
Cornus florida "Cherokee Chief"			■
Cornus florida var. rubra	Red flowering dogwood		■
Cornus mas	Cornelian cherry	■	
Crataegus phaenopyrum	Washington hawthorn		■
Crataegus lavallei	Lavalle hawthorn		■
Fraxinus americana	White ash	■	
Gleditsia inermis (=G.triacanthos var.inermis)	Thornless honeylocust	■	
Juglans nigra	Black walnut	■	
Magnolia soulangeana	Saucer magnolia		■
Malus pumila "Dolgo"	Dolgo crabapple	■	
Malus sp. "Lodi," "McIntosh," "Radiant," "Hope," and "Bechtel"	Apple		■
Morus alba	White mulberry	■	
Platanus occidentalis	Sycamore	■	
Populus deltoides	Eastern cottonwood	■	
Prunus persica	Flowering peach		■
Prunus serotina	Black cherry		■
Prunus subhirtella var. pendula	Weeping cherry		■
Quercus rubra	Red oak		■
Robinia pseudoacacia	Black locust		■
Salix alba	White willow	■	
Salix discolor	Pussy willow	■	
Sorbus aucuparia	European mountain-ash		■
Tilia cordata	Littleleaf linden	■	

Table 3 (Relative tolerance of cultivated species) - *continued*

Species	Common Name	Tolerant[1]	Intolerant[2]
Evergreens			
Juniperus chinensis var. pfitzeriana	Pfitzer juniper	■	
Juniperus virginiana	Eastern redcedar	■	
Picea abies	Norway spruce		■
Picea pungens	Colorado spruce		■
Picea pungens var. glauca	Colorado blue spruce		■
Taxus cuspidata	Upright yew		■
Taxus cuspidata var. expansa	Spreading yew		■
Taxus media "Hicksii"	Hick's yew		■
Thuja occidentalis	Eastern arborvitae		■
Tsuga canadensis	Eastern hemlock		■
Shrubs			
Berberis thunbergii	Japanese barberry	■	
Cornus paniculata	Gray-stem dogwood	■	
Ligustrum obtusifolium var. regelianum	Regel privet	■	
Viburnum dentatum	Arrowwood	■	
Viburnum lentago	Sweet viburnum	■	
Viburnum trilobum	American cranberry bush	■	

[1] Tolerant: 4 to 10 inches of water for 10 days in June of 1972 caused no apparent damage or mortality.

[2] Intolerant: 4 to 10 inches of water for 10 days in June of 1972 resulted in defoliation or death.

Insect and Disease Concerns of Flood Stressed Trees

Natural forests in floodplains have evolved to handle periodic flooding and, therefore, many trees in the flooded areas will indeed survive. However, the 1993 flooding has been prolonged and has occurred during the growing season, adding severe stress. The flooding has included not only areas forested by well adapted *swamp hardwoods*, but has also flooded many urban areas forested by trees that are not well adapted to flooding. In addition, many of the forests now flooded are located behind broken dikes. These forests developed after the dikes were installed in the 1950's and have not previously been flooded, did not evolve to handle periodic flooding and have a different species composition than *typical* bottomland floodplain forests. These forests, along with urban trees, could be highly susceptible to additional tree mortality from insect and disease attacks due to their weakened state.

Trees that survive flooding are in varying stages of health or *vigor*. Vigor is influenced by stress. Prolonged flooding is a major stress, especially during the growing season. Low vigor trees often die quickly from a combination of physical injury and rapid invasion from insects or diseases. High vigor trees may recover very quickly and could be healthy as early as the next growing season. Many trees are somewhere in the middle, struggling to survive and slowly trying to regain a higher level of vigor. Until trees regain an adequate level of vigor, they are susceptible to attack by insects and/or diseases. If an insect or disease is successful in invading a tree, the survival of that tree becomes less likely. The battle to regain vigor and ward off attacks from insects and diseases may continue for several years, causing tree death over a period as long as 3-5 years. Which trees become and continue to be stressed will depend on many factors including a species tolerance to flooding, length of inundation, sediment levels, etc. (see Flood Tolerance of Trees section).

Stress Symptoms

Flood stressed trees exhibit a range of symptoms including leaf chlorosis (yellowing), defoliation, reduced leaf size and shoot growth, sprouting, and crown dieback. Early fall coloration and leaf drop often occur. It also is common for stressed trees to produce large seed crops in years following a stressing event such as flooding. Again, it may not be unusual for symptoms to occur over several years. The symptoms may progress and eventually lead to tree death or they may subside indicating the tree has recovered.

A critical factor in determining the survival of flood stressed trees is whether they become invaded by insects and/or diseases. Flood stressed trees are prime targets for attack by "secondary organisms." Secondary organisms include a wide variety of opportunistic fungi and insects that selectively invade hosts only after they are

weakened or predisposed by stress. It is believed that predisposing stresses such as flooding, drought, and defoliation impair host resistance mechanisms, and trigger biochemical responses which release carbohydrates, glucose, and other nutrients which stimulate secondary insects and diseases.

Further, certain root and collar rot diseases are favored by waterlogged, oxygen-deficient soil conditions, most notably those caused by the water mold fungi, *Phytophthora* spp. and *Pythium* spp.. Flooded soil conditions not only promote reproduction and dispersal of these fungi but also promote the susceptibility of plant roots to infection.

Finally, the wood of trees that have died as a result of the flooding will also be quickly attacked and utilized by wood boring insects and blue staining and decay fungi. Where landowners wish to salvage and sell dead or severely declining trees, they will need to be aware of the decline in wood quality that can occur quickly from insect and disease attack. This can significantly reduce the value of wood products. (See discussion of salvage considerations in Management Implications section).

The following is a list of insects and diseases to watch for:

Insects

Stem boring insects are the major group of "secondary" insects of concern. The most common stem borers are beetles, either adults or immatures (larvae) depending on the species. Other stem borers, which may cause problems on trees, will be a few moth or woodwasp larvae. Stem boring insects can be further divided into ***phloem borers*** and ***wood borers***. ***Phloem borers*** include bark beetles and many of the metallic wood-boring beetles. They are serious pests because the damage they cause occurs in the phloem and outer sapwood layers. These two layers are important in food and water transport and if significantly damaged, trees are severely altered. ***Wood borers*** may spend some time in the phloem layer, but generally tunnel and feed within the wood of tree stems or branches. This tunneling is often not a serious impediment to tree survival though it can significantly reduce the "quality" of any eventual wood products. A major concern with ***wood borers*** is weakening of stems, which may lead to breakage during ice, wind, or snow storms.

Symptoms of stem borers may include small holes in the bark. Entrance holes may have pitch, sap, or sawdust exuding from them. Exit holes are generally very clean and may be round, oval or D-shaped. Removal of the bark should expose larval tunneling. (Bark removal is an additional wound and should only be done on trees already dead or those which are not of high value).

Special management practices for stem borers: 1) Prevent additional wounding or root damage to trees. Wounds create stress and act as attractants to many insects. 2) Sanitize areas by removing and destroying large broken limbs and dead trees. This material may act as breeding sites for stem-boring insects which may

later infest surrounding live trees. 3) Increase tree vigor through light fertilization treatments and watering if soil conditions become excessively dry. (This may be required for 2-3 years). 4) Insecticides rarely help; they should **only** be used for high value trees and following the recommendation of a professional entomologist, arborist or forester. Stem borer insecticides are applied to the tree bark as a protectant; therefore, application must be made prior to infestation.

It is unknown if leaf-feeding (caterpillars) or sucking insects (scales and aphids) will become more of a problem following flooding. Plant stress can alter the biochemistry of trees making nutrients and sugars more available to insects feeding on leaves or sap. This could increase survival of these insects and increase their population size. Outbreaks of caterpillars or scales and aphids could further increase stress levels on trees severely weakened by the flood. Therefore, control of these insects should be a priority on high value trees for the next 1-3 years. This may require insecticide application(s). Insecticide recommendations should follow label guidelines.

There are too many tree species and associated insects involved to make an individualized list of potential insect pests. ***The following trees, however, are notorious for attacks by insects following stressful periods and often require close watch: all pines, oaks, hybrid poplars, birches (especially ornamental white birches), and hickories.*** Also, resource managers should be especially aware of pine bark beetles, *Ips* spp.; twolined chestnut borer, *Agrilus bilineatus*, attacking oaks; bronze birch borer, *Agrilus anxius*; and hickory bark beetle, *Scolytus quadrispinosus*.

Diseases

Armillaria Root Disease

This disease, also called shoestring root rot, can attack hundreds of species of forest, shade, and ornamental trees and shrubs. Although some *Armillaria* species are aggressive pathogens, others are opportunistic and work singly or in conjunction with other secondary action pests. In the Northeast for example, oak trees weakened by stress are often attacked by both Armillaria root rot and the two-lined chestnut borer. Armillaria root rot is commonly associated with drought-stressed trees, an association that is well documented by research. Excess soil moisture may be as stressful as drought to trees because it can cause “physiological drought” by interfering with water uptake in oxygen-deprived roots. Excess soil moisture and increased severity of Armillaria root rot have been observed in oak and chestnut species in Germany and Austria (Bazzigher 1956), in larch in Japan (Kawada et al. 1962), and in rubber trees in Nigeria (Fox 1964).

Symptoms and Management

Diagnostic symptoms include white colored mycelial fans under the bark, shoe-string-like rhizomorphs, and "honey" mushrooms which are present only in the late summer or fall. Nonspecific symptoms include leaf chlorosis and defoliation, reduced leaf size and shoot growth, crown dieback, and death. (Refer to the enclosed USFS Forest Insect and Disease Leaflet entitled *Armillaria Root Disease* for color photographs of symptoms and information on management practices).

Canker Diseases

A wide range of fungi incite canker diseases in both hardwood and conifer hosts by invading the bark, cambium, and outer sapwood of branches and stems weakened by mechanical injuries, insect feeding, water extremes, or other diseases. Branches and main trunks of trees submerged in flood waters or injured by floating debris will be prime targets for invasion by canker fungi. Some of the most common canker diseases include Nectria, Cytospora, Botryosphaeria, and Botryodiplodia.

Symptoms

Cankers appear as localized dead areas on branches or stems and are commonly associated with wounds or dead branch stubs. They often appear discolored or sunken, and the bark may or may not remain attached to the face of the canker. Some canker diseases such as Nectria produce zonate or target-like cankers in response to successive layers of callus tissue forming at the progressing edge of the canker. Cankers can girdle branches or small stems and result in wilting or dieback. Canker diseases are rarely fatal to their hosts unless large or multiple cankers girdle the main stem.

Management

Because wounding and predisposition play a role in the development of canker diseases, the best approach to management is to minimize tree stress and injuries. See *Management of Flood Stressed Trees* below for more information.

Phytophthora and Pythium Root Diseases

Phytophthora spp. and *Pythium* spp., commonly known as water mold fungi, are ideally suited for waterlogged soil conditions. Plant roots stressed by reduced oxygen in waterlogged soils exude more amino acids and ethanol which attract infective spores to root surfaces. Infective spores are dispersed in surface water such as flood, runoff and irrigation waters. Survival rates of these spores in water has not been widely studied; however, one study demonstrated that spores of *Pythium*

aphanidermatum survived for 185 days after submersion in pond water (Stolzy 1984). This suggests that other species of water mold fungi may have similar survival rates in water. If this is true, an increase can be expected in root and collar rot diseases caused by species of *Phytophthora* and *Pythium*.

Symptoms of *Phytophthora* and *Pythium* Root Diseases

Symptoms include stunting, leaf chlorosis, reduced leaf size, basal stem cankers which often ooze sap, root and collar decay, crown dieback and death. *Pythium* spp. cause damping off and root rot disease on young seedlings in nurseries and can infect nearly all conifers and hardwoods. *Phytophthora* spp. incite root and collar rot diseases on a wide range of nursery and forest tree hosts including:

Fruit and nut trees
apple, cherry, citrus, and walnut.

Shade and forest trees
American and European beech; sweet birch; flowering dogwood; fir; sweetgum; horse chestnut; black, Norway, red, silver, sugar and sycamore maples; pin, and red oaks; pines; yellow-poplar and weeping willow.

Ornamental shrubs
azalea and rhododendron.

Management of *Phytophthora* and *Pythium* Root Diseases

Management strategies for these two diseases must be targeted at nursery operations since little can be done to control these diseases after trees are outplanted. Nursery management practices include:

1. Avoiding planting tree species highly susceptible to *Phytophthora* spp. in poorly drained fields.

2. Improving soil drainage in poorly drained fields.

3. Employing alternative cropping regimes in fields with a previous history of root rot disease. Consider bare fallow for 1 to 2 years to reduce disease inoculum.

4. Using chemical fumigation.

Outplanted trees exhibiting symptoms of root disease may benefit from efforts to enhance tree vigor. (See *Management of Flood Stressed Trees* below for more information).

Management of Flood Stressed Trees

Urban and Landscape Sites

The best approach to managing flood stressed trees is to enhance tree vigor by proper tree maintenance and protection from additional stresses. Tree vigor can be enhanced by fertilizing with a low nitrogen fertilizer, aerating the soil, mulching, and watering if soil conditions become excessively dry. Dead or severely cankered branches should be removed. Prune only when bark surfaces are dry or during the dormant season.

Newly transplanted or mature, high value trees may need protection from leafspot diseases such as anthracnose and from insect defoliators and various sucking insects such as aphids or scales. It should be noted that leafspot diseases are not severe every year. Trees need protection during spring seasons that have frequent rainfall at budbreak and during leaf expansion. Refer to the enclosed USDA Forest Service brochure entitled, *How To Identify and Control Dogwood Anthracnose*, for more information. Although the above mentioned publication deals specifically with dogwood anthracnose, the cultural control recommendations are applicable for leafspot diseases of trees and shrubs in general. A fungicide not mentioned, thiophanate methyl, is labeled for control of anthracnose on shade trees and woody ornamentals. Several tradenames of fungicides that contain thiophante methyl include Cleary 3336, Topsin M, Domain, Fungo and Zyban.[1] Fungicides should be used only to supplement a cultural control program. Read fungicide labels carefully to determine registered uses and application rates.

Forest Stands

Any harvest or salvage activities should create a minimum of damage to remaining or regenerating trees or disturbance to the site itself. Soil compaction, rutting, bark removal, and branch breakage can all act as additional stress on other trees in the stand.

Salvage activities such as "sanitation cuts" can be beneficial by removing breeding material of stem boring insects. (See Management Implications section for additional salvage considerations).

Insecticide use is rarely practical or ecologically sound in forested situations.

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[1] Mention of tradenames does not constitute endorsement of the product(s) by the USDA. Some states have restrictions on the use of certain peaticides, and product registration may change. Check your local regulation and confirm registration for its intended use.

Hazard Evaluation of Flood Damaged Trees

As noted above, flooding results in some trees being stressed, physically damaged, and/or insect and disease infested. These trees possess defects that decrease their structural integrity, making them more prone to windthrow and structural failure. Defective trees located in high use areas such as yards, parks, or other recreational areas are hazardous and pose safety risks to people and property. (The Minnesota Department of Natural Resources, in cooperation with USDA Forest Service, has written a manual entitled, *How To Detect, Assess and Correct Hazard Trees In Recreational Areas*. Copies are available from: Minnesota DNR, 500 Lafayette Rd., St. Paul, MN 55155-4049, price: $6.00).

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Stolzy, L.H. and Sojka, R.E. 1984. [Effects of flooding on plant disease.] In: Kozlowski, T.T., ed. Flooding and plant growth. Academic Press, New York. 356 p.

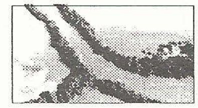
Recommended Books

Insects of Eastern Forests, USDA-Forest Service, Miscellaneous Publication 1426, 1985, 608 pages. (excellent reference for insect biology).

Diseases of Trees and Shrubs, W.A. Sinclair, H.H. Lyon, and W.T.Johnson authors, Cornell University Press, Ithaca, NY, 1987, 574 pages. (Excellent color pictures, very comprehensive).

Insects That Feed on Trees and Shrubs, W.T. Johnson and H.H. Lyon authors, Cornell University Press, Ithaca, NY, 1988, 556 pages. (Excellent color pictures, very comprehensive).

How to Detect, Assess and Correct Hazard Trees in Recreational Areas, Minnesota Department of Natural Resources, 68 pages.



FLOODS

Management Implications

Flooding in bottomland hardwood sites is an important natural occurrence and provides much of the disturbance needed for regeneration of these ecosystems. What has been unusual about the floods of 1993 is the combination of length of inundation, growing season occurrence, and flooding of urban and non-floodplain forests.

Tree Recovery

Tree recovery following flooding is relative. A logger, urban forester, or wildlife manager (as examples) may view a tree's recovery from vastly different perspectives. For example, the logger who seeks a long, defect-free straight trunk will be discouraged if a few inches of terminal dieback results in vigorous lateral branch growth and subsequent poor form. An urban forester, however, may be concerned about the potential hazard of dead branches. The loss of a mast crop may be considered a serious problem to a wildlife manager, but the logger may see it as a minor one.

Regardless of the perspective used to define tree recovery, trees need to build up food reserves for future stress conditions such as another flood or a drought. However, environmental conditions (prolonged flooding or rapid drying of soil) often limit recovery.

Factors Affecting Management

Natural resource managers should be aware of the following management implications when evaluating the consequences of the ***Floods of '93***.

- There will be a significant increase in disturbed sites as a result of siltation and scouring. Normally this would provide an excellent seedbed for many of the pioneer species that occur on bottomland sites. The problem is timing; seeds will not be available again until early next growing season and a percentage of these sites may be lost to herbaceous competition. In addition, herbaceous plants will replace the woody understory in many forest stands.

- There may be a bumper seed crop in 1994 as a result of the stress induced by the prolonged 1993 inundation.

- The loss of litter and the duff layer may make the soil more susceptible to temperature variances. This may affect seed germination (particularly of non-floodplain species) as well as delaying spring leaf-out.

- There will be mortality across the continuum from mature trees to new regeneration due to the prolonged inundation. Death will probably come

slowly to some species over the next 1-4 growing seasons. Consequently, when low vigor trees are harvested, one should not depend on sprout origin material making up much of the stocking in the next stand.

- Opportunities may increase for planting in bottomland sites as a result of severe scouring or siltation of agricultural fields. The only long-term practical solution for some of these sites may be restoration to bottomland hardwood species by planting. (Refer to Tables 1 and 2 in the Flood Tolerance of Trees section of this resource packet when selecting species for planting.)

- Diameter growth of most flood-intolerant species usually is reduced by prolonged flooding of soil during the growing season. Sometimes the reduced growth occurs so long after flooding that other causes are sought. In contrast, flood tolerant trees may make a spurt of diameter growth during the first year of flooding. For example, a Mississippi study found that the diameter growth of green ash, which is often categorized as relatively tolerant of flooding, was 80 percent greater than normal when water remained on the ground from spring through August.

- Sometimes it is difficult to make valid estimates of wood production in flooded trees by measuring changes in stem diameter, especially in young trees. For example, short-term flooding of some woody ornamentals increased stem diameter largely because of an increase in bark thickness rather than increased wood production. Forest trees may respond to flooding in a similar manner.

- Reduced height growth of many flooded conifers and hardwood trees has been shown in experiments with potted plants. Additional studies have found that height growth of some flood-tolerant species may be increased by flooding if the water is flowing.

- The shallow root systems of trees growing in poorly aerated (flooded) soils often make them prone to windthrow. Windthrow is a management concern in both urban and forest settings.

- Landowners who are "investors" in timberland can deduct a flood-related casualty loss if the value of the loss is 10 percent or more (minus any income from salvage) of their adjusted gross income. Flood victims who plan to reforest their land for timber production are eligible for a 10 percent tax-credit and can amoritize 95 percent of the cost over a 7-year period.

Salvage Considerations

Little information is published on how much time is available to salvage dead or declining trees before stain-causing fungi begin to significantly degrade sawlog material. Since much of the flood-induced mortality will probably occur over the next two growing seasons, there may be a one to two-year period to accomplish salvage.

Stain-causing fungi enter first through points of injury such as damaged bark and broken limbs, so if there is no apparent mechanical injury, there may be a little more time before stain develops. Light colored hardwoods (ash and birch, for example) stain faster than dark colored species such as oak and walnut. Cottonwood and silver maple will probably deteriorate the fastest.

Foresters must be prepared to develop "salvage plans" as a part of an overall management plan for flooded forestland. Local sawmills, however, may be unprepared to process the dead and dying timber especially if the supply exceeds mill capacity. Species composition may also pose a problem in the marketplace.

Timber harvesting frequently contributes to increased soil wetness and reduced soil aeration by compacting soils and damming subsurface water flow. High soil moisture also results from the large reduction in transpiration which follows harvesting. These factors can impact residual trees following a large-scale salvage cut.

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Levee Armoring: Woody Biotechnical Considerations for Strengthening Midwest Levee Systems

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Introduction

The floods that occurred throughout the Midwest during the summer of 1993 were of historic proportions (Hanhack, 1994). Because of the duration, velocity and extent of floodwaters, levee failures resulted in extensive damage to agricultural land, rural and urban infrastructures, and human resources (Scott, 1993).

In Missouri, agricultural floodplain areas along the Mississippi, Missouri, Grand, Chariton, Locust, Thompson and Osage rivers were particularly impacted. According to the State Emergency Management Agency, about 3.1 million acres of Missouri land flooded. The Food and Agricultural Policy Research Institute estimated crop losses on this land at $247 million. The USDA Soil Conservation Service (SCS) predicts that reclaiming cropland damaged by flooding will exceed $600 million (Soil Conservation Service, 1993).

Secondary levees associated with major rivers and upstream tributary levee systems in Missouri experienced an estimated 2019 levee breaks (Soil Conservation Service, 1993) during the 1993 floods. A number of non-scientific surveys conducted by Missouri Department of Conservation and SCS personnel after the flooding indicate that levees with forested buffer zones or with woody vegetation cover on the levees may have saved many levees from damage and reduced the severity of damage to others.

The beneficial effects of woody vegetation is not surprising considering the increasing use and successful applications of woody vegetative materials in stabilizing slopes and reinforcing soils (Gray and Leiser, 1982; Soil Conservation Service, 1992). In light of these recent observations and uses, this paper examines the potential woody interactions with levee systems and presents some levee armoring designs.

Woody Plant Interactions With Levee Systems

Woody corridor development and woody levee cover appear to be critical elements in increasing levee integrity (Shields and Gray, 1993).

An informal aerial review of a segment of the Missouri main-stem levee showed a dramatic increase in levee failure (Table 1) as woody corridor width decreased. Observations from Missouri Department of Conservation personnel (Young, 1994) contend that tree screens are credited with saving levees as well as floodplain fields from flood scour. Field reviews completed in February 1994 by the authors (unpublished) on a portion of Shoal Creek in Caldwell county revealed only a single levee break (internal tile line failure) with woody cover and woody corridors of 20 to 100 meters in width. Levees, with woody corridors completely absent and in grass sod, upstream from the wooded corridor site experienced multiple breaks in a similar length of levee.

O.S. Scheifele, an early advocate of woody vegetation for protection of streambanks and levees, made similar observations following the flood of June, 1927 near Memphis, Tennessee (Scheifele, 1928).

> "It was interesting to inspect various sections of the levees after the big flood. Wherever a heavy stand of native willows or other forest trees were growing in the burrow (sic) pits and on the land between the river the erosion from wave action and current was very slight and on miles of levee where tree growth existed no injury was caused whatever. On the contrary, where land was cleared and there were no obstructions to break the waves, injury and destruction were evident along the entire distance."

The relationship of woody plants and levee integrity may be the result of woody plant effects on altered river hydraulic conditions and biomechanical interactions of woody root systems and earthen levee material.

Hydraulic Considerations

For many years engineers have used Manning's equation (Chow, 1959) to describe steady uniform flow in an open channel where:

$$V = 1.49\, R^{(2/3)} S^{(1/2)} / n \qquad \text{and}$$

V = the mean velocity of flow in feet per second
R = the hydraulic radius of the channel in feet
S = the slope of the energy grade line in feet per foot
n = the coefficient of roughness

The hydraulic radius is dependent on the geometry of the channel cross section; the slope of the energy line is essentially the average slope of the channel bottom; and the coefficient of roughness is a measure of the roughness of the channel boundary. With all other variables held constant, the greater the roughness, the slower the velocity of flow.

The roughness coefficient is dependent on many factors but the two most important influences are surface roughness and vegetation.

In natural streams, this coefficient ranges from approximately 0.025 for clean straight channels to 0.150 for floodways with heavy stands of timber and underbrush (Chow, 1959). This range represents a potential six-fold change in velocity as a result of roughness alone. During a flood event, the vegetation in a wooded stream corridor creates drag forces opposing the flow which dissipate energy, and reduce flow velocity (Henderson and Shields, 1984). Flood waters are less likely to cause erosion and scour as energy is dissipated by vegetation. In addition, sediment carried by flood waters will drop out of suspension as velocity is slowed.

Biomechanical Considerations

Naturally vegetated stream corridors exhibit a level of channel stability that is lost when vegetation is removed. In addition to slowing the velocity of flow, vegetation helps protect streambanks from surface erosion and slope failure. Tall grass and brushy vegetation tend to lay down during a flood event, dissipating energy and providing resistance to scour (Henderson and Shields, 1984). Root fibers, especially woody root fibers, increase the shear strength of the soil (Schiechtl, 1980). Roots also create a fibrous mat that resists scour of the surrounding soil matrix (Henderson and Shields, 1984). Vegetation further enhances slope stability by transpiring moisture from the root zone to the atmosphere (Gray and Leiser, 1982).

Woody material associated with levee systems raise a number of engineering concerns (Shields and Gray, 1993). Hynson et al. (1985) list three potential problems posed by trees on levees. First, they suspect that seepage could occur if tree roots penetrate into embankment areas that have high pore pressures during flooding. Second, windthrow could lead to slope stability or seepage failure. Third, trees can hinder inspection and flood fighting if lower limbs are not periodically pruned. Hynson et al. (1985), however, did not document any failures that actually occurred by these mechanisms. Shields and Gray (1993) note that root-induced piping has not been documented scientifically. Windthrow is a valid concern for isolated or widely scattered trees but is less likely for dense uniform stands and not a concern for small trees and shrub growth forms. Access for inspection and flood fighting may be safeguarded by designs that permit travel access on levees.

Levee Armoring Designs

Based on hydraulic and biomechanical considerations, we believe maximum levee protection should incorporate both woody corridors and levee woody plantings. Four designs using combinations of woody materials are suggested for trial use and study on Midwest levee systems. All the following designs would be incorporated with a river side woody corridor of appropriate width.

It is important to note that the use of woody material on levees is not an accepted policy by any federal agency at this time.

Levee Shrub and Grass System

Design
The first design uses woody shrub material on the river side of the levee from the toe to the levee crest (Figure 1). A number of native shrub species are suitable for establishment and use (Table 2) with this system. To reduce the chance of insect and disease problems and to increase site diversity, a minimum of three species is recommended. Growth forms and site requirements of the selected shrubs should be compatible. The crest and field side levee slopes would be vegetated with grass sod.

Management
A periodic cycle of cutting (5-7 years) would be the only needed woody maintenance. This will allow the shrub regrowth to maintain a vigorous and healthy vegetative condition and allow improved inspection. For the sod areas on the levee, the use of current U.S. Army Corps of Engineers maintenance guidelines (1982) would be continued.

Advantages and Disadvantages
This design scenario would aid river side slope stability and protect the levee against wave wash. Habitat diversity would be increased by the addition of a shrub component. Free access to the top and field side of the levee would be maintained for any necessary high water inspections and operations.

Levee Shrub System

Design
The second design uses woody shrub material on both sides of the levee (Figure 2). Choice and selection of shrub species would be similar to design 1. The top of the levee would be maintained in a grass sod.

Management
Woody shrub management would be similar to design 1. To maintain adequate protection for the levee, cutting shrubs for rejuvenation should be avoided on both sides of the levee within the same segment. Annual mowing of the top of the levee would be needed to maintain sod cover and prevent woody encroachment.

Advantages and Disadvantages
The advantages and disadvantages would be similar to design 1 with increased acreages of diversified habitat and added field side slope protection. Visual inspection capabilities and access would be reduced.

Levee Tree and Shrub System

Design
The third design uses tree and shrub material on both sides of the levee (Figure 3). Tree establishment would be continuous from the woody corridor to the midslope on the river

side of the levee. Shrub material (Table 2) would complete the front slope to the levee crest and cover the top half of the field side of the levee. Tree species would cover the lower half and extend into the former field area. The crest would be maintained in a grass sod. Native riparian tree species (Table 3) should be used.

Management

Shrub management of this system would be similar to design 2. An added management consideration would be required for the levee tree component. Optimum tree growth occurs generally between 30 - 60 years of age. Management schemes, such as periodic tree harvests, would be needed to maintain the levee stand in this age range.

Advantages and Disadvantages

Advantages of this system would include increased lower levee slope protection, periodic saleable wood products, increased habitat diversity, debris and sand filtering, and continued access along the top of the levee. Disadvantages include reduced access to both the levee front and back slopes.

Levee Tree System

Design

Design four would establish and maintain a forested community over the entire levee structure and river side corridor. Adequate tree densities would be needed to keep stands fully stocked to reduce the possibility of wind-throw hazards. Species selection (Table 3) should be guided by site conditions, landowner objectives, and maximization of site diversity and income.

Management

Optimum tree growth occurs generally between 30-60 years of age. Management would be based on keeping the stand in pole and small sawtimber size-classes which would reflect this age range. Vigorous tree growth and stand health would allow maximum tree densities and strong root systems. Periodic tree harvests would be needed to maintain this condition and allow capture of saleable wood products.

Advantages and Disadvantages

Advantages of this system would include increased total levee slope protection and stability, periodic saleable wood products, debris and sand filtering capabilities, and reconstruction of a natural riparian ecosystem system. Disadvantages include very limited access to entire levee system.

Summary

Historically, flood protection measures in the Midwest have ignored and actively excluded woody vegetation from levee systems. In light of recent reviews of levees in Missouri, the attitude that woody vegetation is undesirable and negatively affects the maintenance and stability of the levee structures may be unjustified and an unwarranted position.

Instead of excluding woody vegetation, levee designs should actively incorporate woody materials as corridor plantings between the levee and river and as protective cover on the structure itself as long as inspection and flood fighting capabilities are maintained.

Levee armoring with properly designed woody material will slow floodwater velocities, dissipate energy, reduce scouring potential, and increase soil shear strengths. These hydraulic changes and biomechanical attributes would increase levee protection and stability, improve wildlife habitat diversity, establish natural riparian ecosystems, reduce maintenance costs, reduce flood damage to floodplain fields by trapping sediment and debris, and provide an opportunity for secondary wood products to be harvested.

Field studies and research are needed to evaluate the full potential of levee armoring designs and reduce the negative aspects such as reduced access and inspection capabilities.

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Table 1. Aerial observations along the Missouri levee system, April 1994 by John Dwyer.

Corridor Width (tree crowns)	Levee Breaks (number)
<2	44
2-3	16
4	6
>4	1

Table 2. Selected shrubs for use in Midwest levee armoring.

Common Name	Species
deciduous holly	*Ilex decidua* Walt.
swamp privet	*Foresteria acuminata* (Michx.) Poir.
heart-leaf willow	*Salix rigida* Muhl.
gray dogwood	*Cornus racemosa* Lam.
redosier dogwood	*Cornus stolonifera* Michx.
arrowwood	*Viburnum dentatum* L.var.deammii (Rehd.) Ferm.
witch-hazel	*Hamamelis virginiana L.*
red willow	*Salix discolor* Muhl.

Table 3. Selected trees for use in Midwest levee armoring.

Common Name	Species
silver maple	*Acer saccharinum L.*
pecan	*Carya illinoensis* (Wang.) K.Koch.
green ash	*Fraxinus pennsylvanica* Marsh.
Eastern cottonwood	*Poplus deltoides* Marsh.
black willow	*Salix nigra* Muhl.
pin oak	*Quercus palustris* Muenchh.
river birch	*Betula nigra L.*
boxelder	*Acer negundo L.*
hackberry	*Celtis occidentalis L.*
sycamore	*Platanus occidentalis L.*
black walnut	*Juglans nigra L.*

Levee Armoring Considerations

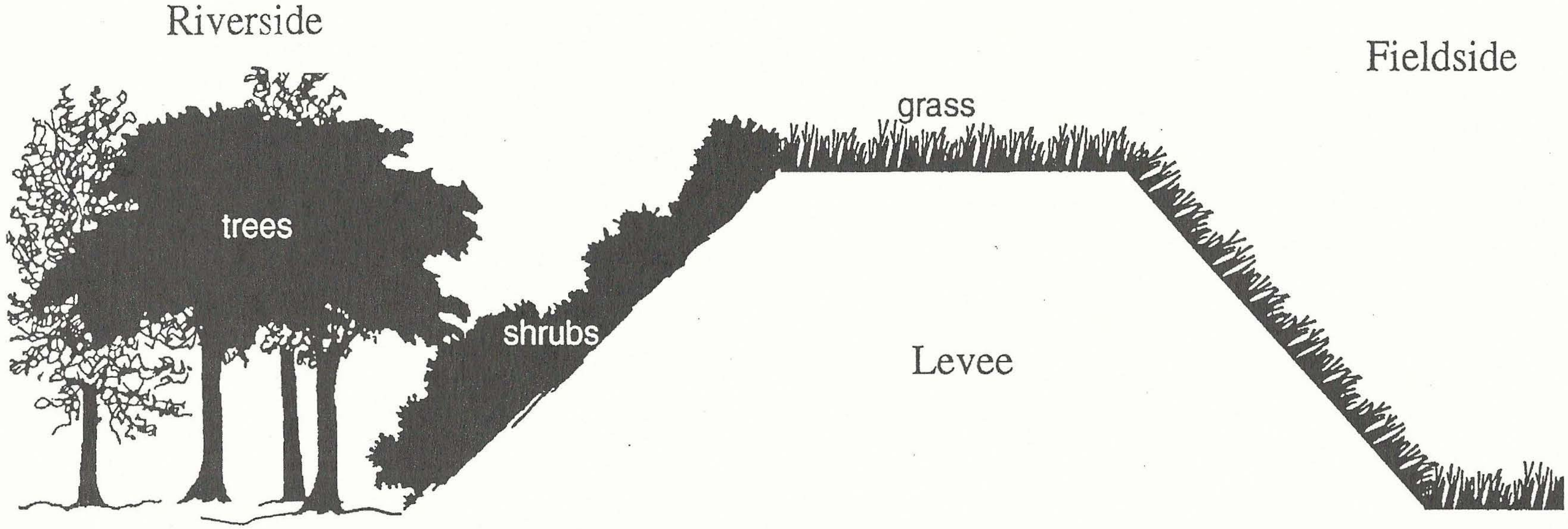

Figure 1. Levee Profile with Tree Corridor and Riverside Shrub Armoring

Levee Armoring Considerations

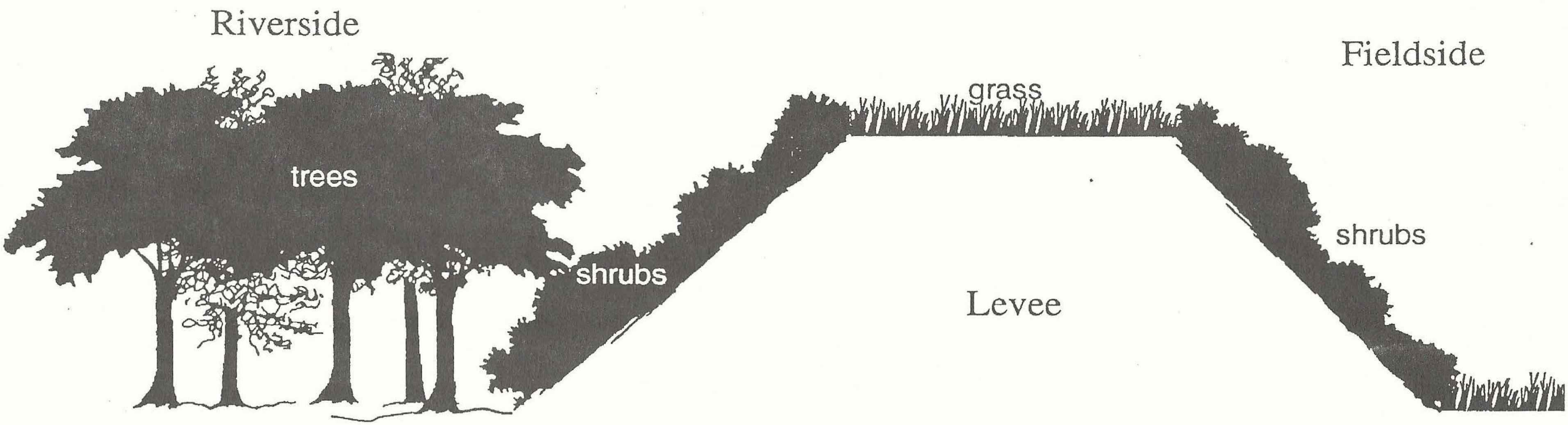

Figure 2. Levee Profile with Tree Corridor and Riverside and Fieldside Shrub Armoring

Levee Armoring Considerations

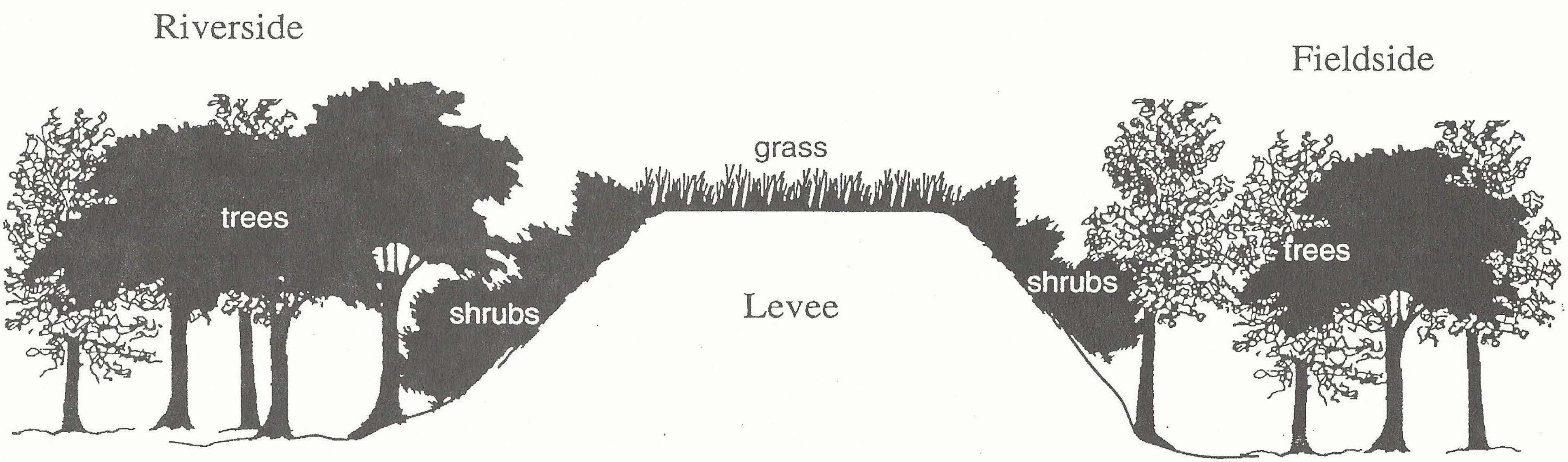

Figure 3. Levee Profile with Tree and Shrub Armoring

Levee Armoring Considerations

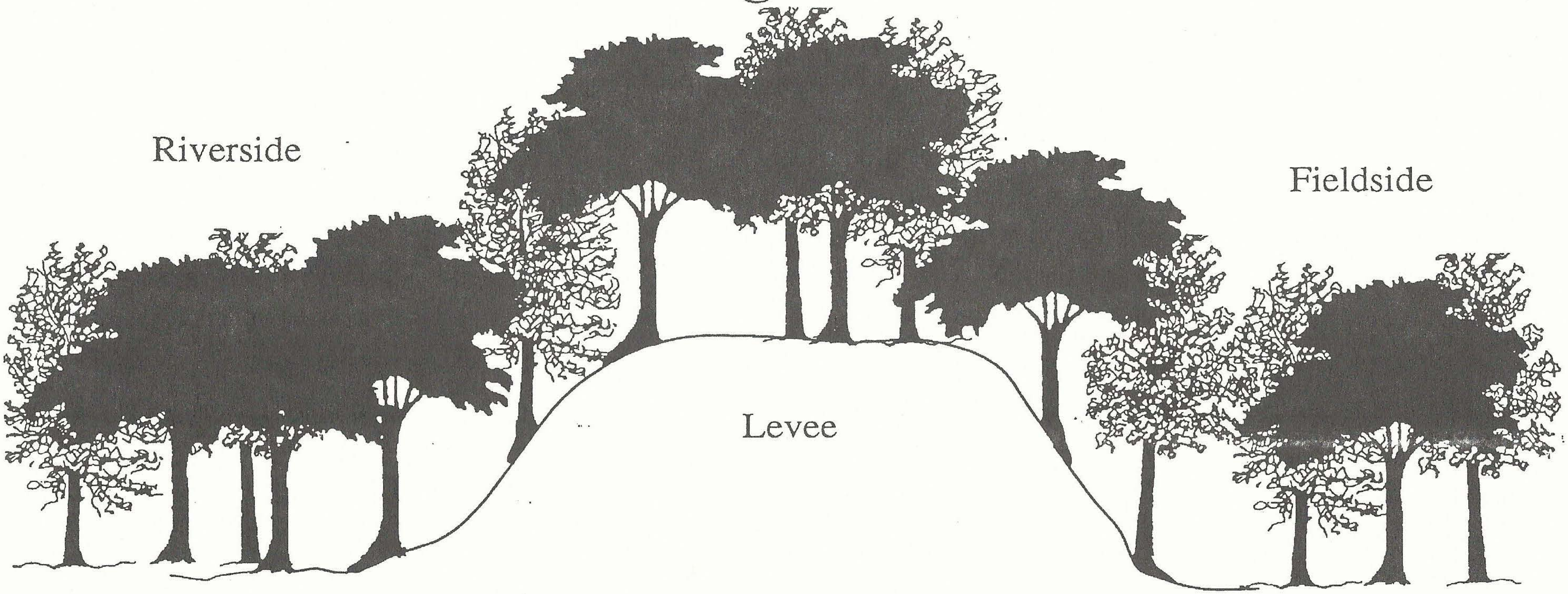

Figure 4. Levee Profile with Complete Tree Armoring

Forestry Strategies To Protect Floodplain Agricultural Systems

Frank Hershey, Douglas Wallace and John Dwyer

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Presented at the Restoration of Aquatic Ecosystems symposium, The Association of State Wetland Managers, St. Paul, Minnesota, June 20-23, 1994.

Introduction

Damages to agricultural lands and associated infrastructure from the record floods of 1993 in Missouri were staggering. Floodplain croplands, some of the most valuable and productive in the state, were impacted by debris accumulation, sediment deposition and scour erosion. Cropland damaged by sand and scour for just the Missouri portion of the Missouri River was estimated at 455,000 acres, with an estimated $500 million to reclaim sand damaged land (Soil Conservation Service, 1993). Additional millions of dollars will be required to rebuild levee breaks and restore fertility to flood-damaged cropland. In some instances costs for recovering the land exceeded its market value as cropland.

Questions were raised about the future crop production capabilities of the damaged land. Programs activated to assist with the clean-up and repair of damaged farmlands in the floodplains and the associated agricultural infrastructure were designed to make repairs to restore pre-flood conditions. Mixed with the damages were some excellent examples of floodplain use and management that could serve to guide changes in the way floodplain agriculture is conducted to avoid or minimize future severe flood damages. The strategic use of trees in floodplain agriculture is the key to accomplishing the desired changes and realizing the benefits.

Role of Trees In Floodplains

Historically, trees performed some important functions and their presence in the river bottomlands significantly influenced the floodplain landscapes farmed today. Woody vegetation stabilized the soil and controlled scour erosion. Stands of trees absorbed the energy from floodwaters and caused the deposition of water borne sediments. Floodplain forests stored the overflow waters and drove many of the processes to support aquatic life systems and improve water quality.

Following the 1993 floods it was apparent that there were not enough trees in the floodplain. Extensive damages to floodplain cropland and the associated agricultural infrastructure were preventable with the strategic placement of trees and with more effective management of opportunities offered by natural stands. Major forms of

damage that can be addressed by manipulation of tree resources are debris accumulation, scour erosion, and sand deposition. Also, woody vegetation appears to be under-utilized and discriminated against as a biological system of levee protection.

Brumfield (1993) described the influence of strategic cottonwood plantings on debris trapping and sand deposition in the Thompson Bend high flow channel of the Mississippi River in Mississippi County Missouri. Satterlund (1972) discussed the use of Manning's equation in hydraulics to express velocity. There is a ten-fold increase in the roughness coefficient factor of Manning's equation between flow over a packed clay surface and a surface composed of dense shrubs and forest litter. Woody vegetation on floodplains causes significant reductions in flow velocity causing the deposition of suspended particles and trapping debris.

Scour erosion is controlled by the dense mat of intertwined, fibrous roots that reinforce the top foot of soil in the forest floor. Perry (1989) reported that trees develop root systems that extend horizontal distances of up to 2 times tree height. Any one square foot of soil on the forest floor will contain the intermingled roots of 7 or 8 different trees.

During flood events, levee systems frequently function as stream banks. Shields and Gray (1993) reported positive effects of woody vegetation on levees in California supporting observations in Missouri during and after the 1993 floods that trees could be excellent levee protection.

Levee Maintenance

Scheifele (1928) installed and documented the effectiveness of numerous levee and streambank protection plantings utilizing woody vegetation, many in the Midwest. He also discussed the concerns of engineers about woody vegetation on constructed embankments. Three major concerns are the basis for levee maintenance standards that specify that no woody vegetation be allowed on levee embankments.

1) Large trees will windthrow from saturated levees, removing a large soil mass and creating a breach point in the levee.

2) Large tree roots will extend through the levee and cause piping during floods. This is primarily a concern when large old trees die.

3) Woody vegetation attracts burrowing wild animals to the levee embankment and their activities create breach points in the levee.

These concerns must be addressed and their validity documented or disproved before recommendations to armor levees with woody vegetation can be successfully advanced. Bottomland hardwood ecosystems in the floodplains of Midwestern streams have been converted to agri-ecosystems. These converted systems lack stability and are more susceptible to environmental damage (Bratton, 1993). Restoring trees to these systems can add stability, increase diversity and supplement the agriculture systems that will continue to occur on floodplains.

Agroforestry Systems

Trees that work for agriculture are called agroforestry systems (U.S. Forest Service, undated). Some agroforestry systems with specific application to floodplains include windbreaks to stabilize sandy soils, filter strips and riparian areas for bank stabilization and water quality, alley cropping for enhanced crop production and protection, wildlife habitat, woodlots and fuelwood plantations. Agroforestry systems are installed for several objectives including profit, productivity enhancement, energy conservation, natural resource conservation, environmental diversification and modification and to enhance the environment for people.

Hershey and Wallace, (1993) found that waterbreaks of trees planted perpendicular to the flow of high energy flood waters were economical based solely on the reduction of damages to crops, assuming floods of 10 year frequency. Tree species adapted to the floodplains include species valued for their lumber, and pecan, valued for the nut crop. Agroforestry systems designed specifically for the floodplain are needed to develop and analyze all of the possible alternatives of maintaining productive agriculture while increasing environmental stability and protecting the agricultural infrastructure of the floodplains.

Floodplain Agroforestry Systems

The system designed for Thompson Bend is an example of the potential benefits of this system. The Thompson Bend plantings trapped debris so efficiently that mountains of debris rode the trees down, submerging their tops in the 1993 floodwaters and killing sections of the plantings. However, the tree rows still functioned to hold the debris and deposit sand within the confines of the dead tree rows and leaving the crop land clear and unscoured for 1994 planting.

Conclusions

Agriculture will always have a role in the fertile floodplains of Midwest streams. Agroforestry systems are one means of creating a stable balance between human needs and natural forces.

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Tree Planting Enterprises on Flood-Damaged Farmland

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Introduction

In the aftermath of the Great Flood of 1993 eight Midwestern States lost agricultural crops valued at $1.4 billion on six million acres. Missouri was especially affected because 498 miles of the Missouri and 487 miles of the Mississippi Rivers flow through or adjacent to the State boundary.

Floodwater damage to agriculture land in the floodplains of the Missouri River left behind a landscape scoured by erosion and inundated with sand deposits. In Missouri, the Soil Conservation Service estimates the flood left 60 percent (455,171 acres) of the previously cropped Missouri River floodplain covered by sand. Over 91,000 acres had sand deposits which averaged 24 inches in depth. At this time accurate information is still not available on how many acres were so severely damaged that traditional reclamation is not physically nor economically feasible.

However, it is safe to say that many landowners and even communities are looking at the social, environmental, and economical aspects of new alternative uses for the floodplain and its river corridor.

Purpose

Today, I would like to talk with you about tree plantings as an enterprise, but not in the sense that this is an economic activity, but from the standpoint of a daring new initiative. Forest researchers in the early to mid-seventies (Dutrow et. al 1970; Porterfield 1975) conducted economic evaluations of short rotation woody crop systems. These studies concluded that while fast-grown tree plantings are economically viable, they still can not financially compete with soybean production. A recent study was commissioned by the Environmental Protection Agency and conducted by the Center for Agriculture and Rural Development at the University of Missouri. The purpose of this study was to perform an economic analysis of various alternative floodplain management scenarios. This study concluded that although short rotation woody crop systems (hybrid poplars) and hebaceous energy crops (such as switchgrass) had positive net present worths they could not compete with corn, soybeans, and wheat.

One of the shortcomings of this study was the failure to include the high costs of levee repair into the costs of crop production. Such exclusions beg the question: What social costs are people expected to pay for crop production in the floodplain? Another problem which exists is the paucity of data on yield and production costs for switchgrass and

hybrid poplar production in the Midwest, especially on deep sands.

However, the authors of this study do conclude that there is evidence which suggests that short rotation woody crop systems and hebaceous energy crop species can be successfully grown in areas susceptible to flooding. They go on to point out that these crops can provide benefits such as riverbank stabilization and levee protection, but these benefits are not quantified.

Recent studies (Doan and Ranney 1994) from Oak Ridge National Laboratory suggest that "efforts are justified to thoroughly examine overall benefits and costs of planting flood-prone agricultural areas within the Mississippi River valley to energy crops to reduce damages and costs related to flooding. In the interim, the facts are these: the levees are repaired, or for the most part, will be repaired, and crop production will continue in the floodplains.

What role can tree plantings play in the restoration and recovery of these dynamic riverine systems? In the near term, the role is not the traditional one of displacing crop production with tree plantations either as short rotation woody crops for fuel energy or even some alternative building material product (i.e. panel board). Farmers do not buy into tree planting as an economic alternative per se because they feel as though they could never exercise a harvest alternative in the future even if they wanted too because of section 404 wetland regulations.

One successful example of a working waterbreak can be seen at Thompson Bend on the Mississippi River in Mississippi County, Missouri. These cottonwood plantings established on former row crop land have demonstrated important functions which have included debris screening, uniform sediment deposition and elimination of scour erosion.

In informal discussions with farmers who farm the floodplains along the Missouri River around Brunswick and McBaine, Missouri, it was learned that they feel as though the tree buffer can play a role in protecting the floodplains. Some farmers would hope that the narrow tree buffer along the Missouri River could be widened.

Economic Benefits

I have identified four economic benefits "savings" from planting trees between the mainstem levee and the river bank:

1) There will be a reduction in levee failure. I am not saying that levees will not be breached during floods. What I am saying is that levees will not be destroyed, although there may some topwash and sidewash. Trees planted in a wide enough corridor on the inside of the levee in areas of high energy such as a bend in the river (where past experience has shown levee failure) can reduce the flow rate and dissipate water energy.

   The Corps estimates the current cost of new levee construction at $240,000 per mile. This cost includes the cost of fill material, seeding, mulching, drainage, rock surface, standard scraping and maintenance. In the area of Saline County, Missouri, this cost

represents an average of $400.00 per acre.

2) There will be a reduction and elimination of sand deposition on tillable ground behind the levee. In places along the river between Brunswick, Missouri, and McBaine, Missouri, there can be seen depositions of sand within the tree line along the riverbank which is actually higher than the man-made levee. The cost of sand removal is estimated at $1,100 per acre. However, I suspect this is an optimistic estimate.

3) There will be a reduction in the government funds expended for corn price supports. Assuming a target price of $2.75 per bushel, and an average projected farm or market price of $2.25 per bushel, then the deficiency payment is $2.75 - $2.25 = $0.50 per bushel. Furthermore, assuming an established corn yield of 100 bushels per acre, then the payment is $50.00 per acre (100 bushels per acre x $0.50 per bushel deficiency payment).

4) There are soil erosion control benefits arising from timber production. Findings from a recent study (Noweg, 1994) have shown that the average present value of social benefits per acre obtained through the conversion of erodible agricultural lands in Mississippi to pine plantations was a positive $138.94 at a 4% real discount rate. For lands in the floodplain we simply do not know what the actual savings from soil erosion reduction would be as a result of tree plantings.

Future Research

I will conclude my presentation by telling you about a research project which we have initiated along the Missouri River within the Eagle Bluff Wildlife Area. This 3,636-acre tract just southwest of Columbia, Missouri, is designed to be the largest cooperative project in the nation utilizing treated wastewater effluent for wetland management.

The area selected for the tree plantings lies approximately 400 feet east of the Missouri River bank and adjacent to a 3,000-foot break in the main levee. The purposes of this project are to determine if specially selected fast-growing tree species can be successfully established and grown in deep sand deposits. A longer term goal is to monitor changes in the development of the organic layer and chemical properties of the soil.

Tree species chosen for study will include; native pecan (Carya illinoensis, Wangenh.), sycamore (Platanus occidentalis L.), eastern cottonwood (Populus deltoides Bartr. ex Marsh. var. deltoides), river birch (Betula niqra L.), and silver maple (Acer saccharinum L.). Each species will be replicated in three plots in each block, and each species will be randomly assigned to a plot. Each plot is 72.0 by 90.0 feet and will contain 50 trees of each species planted on an 8.0- by 10.0-foot spacing. In addition to the five species, a control treatment will be assigned to each randomized complete block. In the control treatment the natural recruitment of trees and other woody vegetation will be monitored, and no artificial planting will be done.

In each plot individual tree survival will be monitored and mortality will be determined.

In addition, the diameter and height of individual trees will be measured and recorded. Also, cost and production data will be recorded for all tree planting establishment and early culturing activities. Individual-tree growth and yield data will be analyzed using analysis of variance statistical methods.

At the research site rainfall will be monitored and recorded using a Tipping Bucket Rain Gauge and electronic Event Recorder. At the ends of each plot a plastic pipe will be installed in the soil. Soil moisture will be recorded at different depths using Time Domain Reflectrometry. These climatic and edaphic factors will be used to study the relationship between depth of soil moisture and tree survival.

I perceive the role of tree plantings to be an insurance policy taken out to protect valuable resources between the main levee and the river bank.

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